Nucleation of Continuous, Conformal and Smooth Ultrananocrystalline Diamond (UNCD) Thin Films

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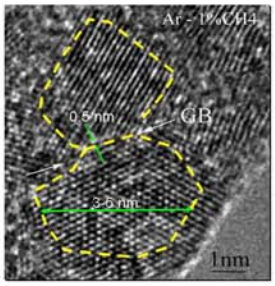
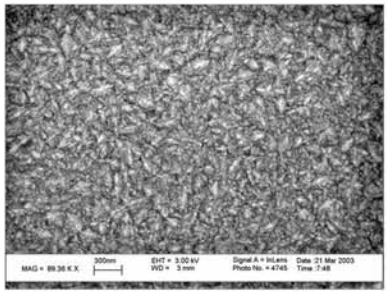
Motivation

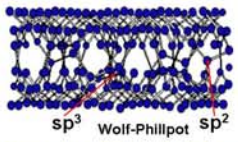
- The ultimate nanoscale structure of UNCD thin films give rise to a number of unique materials properties. The UNCD bulk and surface structure affect its mechanical, tribological, electrical/ thermal transport, and electrochemical properties.
- In order to utilize UNCD thin films in different applications such as tribological and biomedical applications, careful investigation of its surface chemistry and its roughness must be done.

What is UNCD?

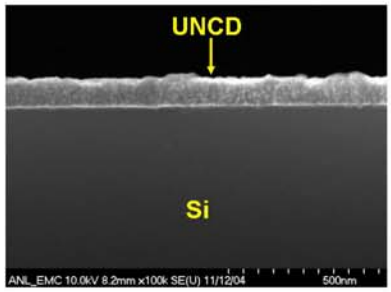




- 3-5 nm grains.
- High-energy grain boundaries (GB).
- 95 % sp^3 bonding structures and 5% sp^2 and other.
- Roughness = ~24nm



Computer simulation of UNCD Grain Boundaries



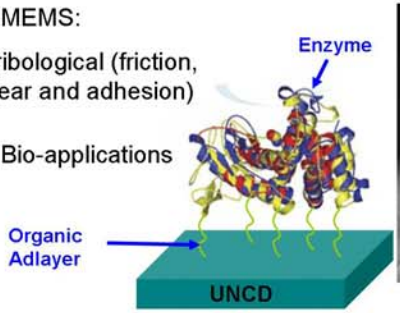
Cross Sectional Image of UNCD Film on Silicon (Si) Substrate

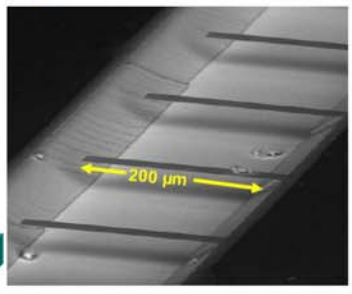
UNCD Potential Applications

- MEMS:

Tribological (friction, wear and adhesion)

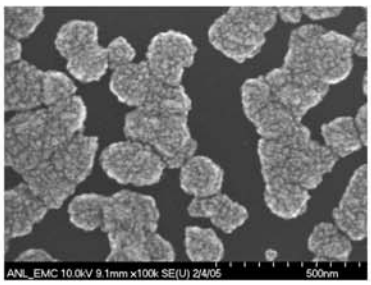
- Bio-applications

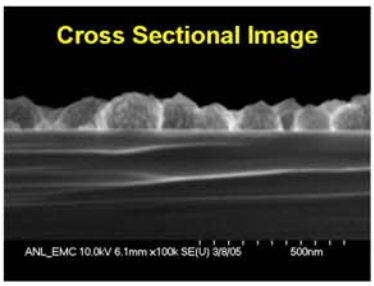




UNCD Cantilever

Limitation of Standard Seeding Methods



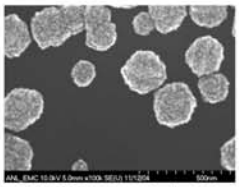


Ultrasonic seeding on Si (100), 20 min growth leads to very poor nucleation density and poor uniformity (UNCD thickness = ~70nm).

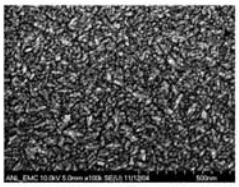
Use Tungsten as a seed layer for higher UNCD nucleation

Tungsten (W) was deposited by two different techniques: Magnetron Sputtering and Atomic Layer Deposition (ALD)

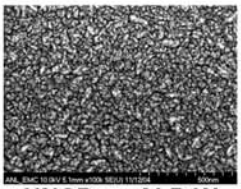
Comparison of different UNCD Films



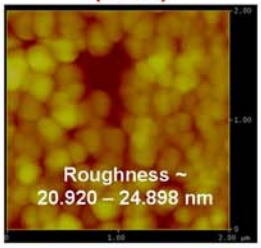
UNCD on plain Si (no W)

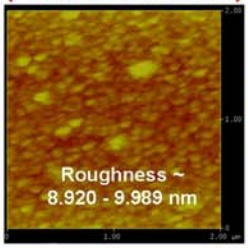


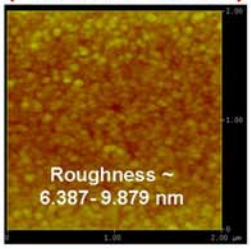
UNCD on Sputt. W (~105Å W thickness)



UNCD on ALD W (~100Å W thickness)







Future Directions

- Investigation of the W-UNCD interface and the chemical nature of the nucleation growth of UNCD on W (why?)
- Investigation of other seeding mechanisms (such as mechanical seeding, dielectrophoresis seeding, and "Rotter" seeding) and how the seeding mechanism can affect roughness
- Investigate the effect of introducing Silicon (disilane gas) during the microwave plasma deposition. The end result will range from Si-doped UNCD (p-type or n-type SiC) to nanostructured SiC/UNCD heterostructure composites, to possibly achieving the synthesis of nanocrystalline SiC films.

ARGONNE NATIONAL LABORATORY

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